مقالات

Page	Title
1	**Steel connections (bolted and welded joints)**
2	Investigation on Behavior of End-plate Connections in Picket Column
3	Effects of bolt-hole clearance and bolt pretension on seismic performance of column-tree moment resisting frames by using incremental dynamic analysis
4	Cyclic Behavior of Moment-Resisting Beam to Column Connections with Enhanced Reduced Beam Section
5	Modeling and a study on behavior of connections of double beams to (CFST)
6	Spring stiffness model for welded Connections exposed to fire
7	Predicting the Behavior of welded semi-rigid Connections exposed to fire Using Artificial Neural Network
8	Introduction of HSS columns splice with pass bolt
9	Modeling and a study on behavior of connections of double beams to (CFST)
10	Parametric Study on Stiffened Column Bases
11	**Stability, fatigue, and fracture in steel structures**
12	Behaviour of Bolted Beam-Column Connections with End-Plates with a Corrugated Reduced Beam Section
13	**Theory of steel structure design**
14	Use of Direct Analysis Method for Steel Structures Design
15	Effect of predominant period on displacement amplification factor in steel frames

Page	Title
16	Evaluation methods for estimate damping in cbf in level of collaps perevention
17	**Steel structures inspection and maintenance**
18	The comparison of series and parallel modes friction dampers and viscoelastic behavior of steel moment frams
19	**Tall building steel structures**
20	Design of Tall Steel Buildings with Steel Shear Walls Based on the Principles of Performance Levels
21	Evaluation of DIAGRID and Tube structural systems in steel high-rise building with rocking motion
22	Effect of different configurations of large-scale zipper elements on seismic behavior of tall frame tube skeletons in near faults
23	Optimization of link beam in the frame braced divergent behavior under seismic forces
24	Evaluation of Seismic Performance of Tall Building with Outrigger and Belt Truss
25	Seismic Demands of Tall Moment Frame Skeletons Exposed to Near-Fault Motions Including Rotational Excitation
26	**Non-building steel structures (bridges, transmission tower, …)**
27	Numerical Study on the Response of Steel Ground Tanks with Free Rocking Motion under Horizontal Earthquake Excitation
28	The Effect of Soil Specifications, on the Maximum Inelastic Displacement of Industrial Steel Structures with Overhead Cranes
29	Evaluate the seismic performance of rocking steel braced frame with tensile stiffness in column-foundation connection
30	**Corrosion and fire resistant steel structures**

Page	Title
31	Heat transfer modeling in concrete-filled hollow steel columns filled with concrete CFT without fire protection exposed to fire
32	Finite Element Investigation on the Behaviour of Open-Web Steel Beams Subjected to Fire
33	**Composite structures**
34	The effect of replacement reduced beam section instead of usual beam in behavior of steel components of RCS connection
35	The effect of thickness of steel cover plate in behavior of RCS connection with reduced beam section
36	The effect of thickness of steel cover plate in behavior of RCS connection with reduced beam section
37	The effect of thickness of steel stiffener in behavior of RCS connection with reduced beam section
38	The Behavior Of Complex Systems, RCS (Concrete Column - Steel Beam) With Bracing Chevron
39	An analytical design method for walls with encased steel shapes
40	Non-linear behavior of CFT columns under axial tensile and axial static loading
41	Parametric Study of concrete filled steel plate composite coupling beams under cyclic loading
42	Lateral Bracing of Bottom Flange in Beam-Slab Composite System by Stiffener Web
43	Investigation into Behavior of SR-CFT Columns under Semi Earthquake and Axial Loading Conditions
44	Numerical Analysis of New Details For Transition Floor Columns
45	Concrete panel effect on shear wall behavior; and stiffness changes reasons in

Page	Title
	composite shear wall
46	**New steel structural systems**
47	Study new methods of steel shear walls fractured and containe
48	Numerical Analysis of seismic behavior of light steel panels with different arrangements bracing
49	An Investigation into the Effect of Connections zone on the Seismic Behavior of All Steel Buckling Restrained Braces: Discussion on projection length
50	Seismic study of cable-cylinder bracing under near field records
51	Seismic performance assessment of hybrid braced cold-formed steel walls
52	Investigation about the seismic behavior of the self-centering eccentrically braced frame with fuses distributed in height
53	Effects of damping of building on seismic behavior of steel braced structures with rocking
54	Evaluation of DIAGRID and Tube structural systems in steel high-rise building with rocking motion
55	Response Analysis and Design of structures with two passive energy dissipation devices in series configuration
56	Investigation of Frame Behavior in Cantilevers Constrained with Coupling Elements
57	Nonlinear Evaluation and Optimization of Frame-type Load Bearing System for Steel Cantilevers with Genetic Algorithm
58	Investigation of energy dissipation mechanisms in post tensioned connection with web hourglass pins
59	Experimental study of steel sheathed cold-formed steel shear wall under cyclic lateral loading

Page	Title
60	Determination buckling mechanism of steel core of buck-restrained braces considering the geometrical imperfection
61	Seismic Evaluation of Self-Centering Steel Braced Frame Under Near-field Pulse-like Ground motions
62	Collapse Assessment of Self-Centering Steel Braced Frame with Posttensioning and Replaceable Fuse
63	Simulation of Crack Growthing of Steel Plate Shear Wall with Opening and Stiffener
64	Performance Evaluation of Tall Steel Building with Dual System of Special Moment Resistant Frame and Buckling Restrained Braced Frame under Far Field and Near Field Earthquakes
65	Seismic Response of hybrid damper tadas and slit the beam-to-column and get the best b and c changes
66	Providing Fragility Curves Of Steel Structures With Buckling Restrained Brace, Subjected To Near-Fault Earthquakes
67	**Seismic design**
68	Improving seismic performance of dual EBF frames in high rise buildings using performance based plastic design
69	Investigation on Earthquake Energy Dissipation Mechanisms in Steel Structures with Concrete Shear Walls using IDA
70	Study of Steel Frames with CBF Performance with Out of Plane Connection
71	Capability of Conventional and Modern Elastic Load Pattern Elastic Load Patterns of Pushover Analysis and the Impact of Pulse-type Near Fault Motions in Predicting Seismic Demand of the Steel Moment Frame
72	Mapping the Seismic Performance of Mid-Rise Steel Frames under Near Field Earthquakes in Tehran Region

Page	Title
73	Investigating the performance of AIDA method in evaluation of three-dimensional structures
74	Illustration of the Directivity Effects on Seismic Response of Dual Resistant Systems with Stiffened Chevron Braced Panels
75	Investigation on Earthquake Energy Dissipation Mechanisms in Steel Structures with Concrete Shear Walls using IDA
76	Evaluation of Nonlinear Dynamic Responses of a Single Degree of Freedom System with Different Plasticity Models Subjected to Earthquake Loading
77	Study the seismic behavior of Multistory-X bracing system and compare with chevron braced system, using incremental dynamic analysis (IDA)
78	Nonlinear Dynamic Behavior X-bracing systems with Lower Grade Steel Under Near and Far Field Earthquakes
79	Evaluation of behavior of semi-supported steel shear walls with opening
80	**High strength steel**
81	Utilizing Q&P Heat Treatment to Produce an Advanced Steel with High Yield Strength
82	**Experimental studies**
83	Laboratory evaluation of the necessary outer length of anchor bolts in the steel plates with welded connection
84	Performance of cold-formed steel shear walls with single and double sided steel sheet sheathing subjected to cyclic loading
85	Evaluation of gypsum and fiber cement boards cladding on seismic behavior of steel sheathed cold-formed steel shear walls
86	Experimental investigation of the behaviour of reduced long link section to column connections

Page	Title
87	Experimental and Numerical Evaluation of Conventional Moment Connection of I-Beam to Double-I Built-Up Column
88	**Seismic retrofitting and rehabilitation**
89	Template for 2nd International Conference of Steel and Structure Conference
90	Time history Analysis of a Five Story Steel Moment Resistant Frame in Rehabilitation with U-shaped Metallic Yielding Damper.
91	Experimental studies of new hybrid inertia rotational friction damper and compare its performance with inertia rotational viscous damper
92	Time history Analysis of a Five Story Steel Moment Resistant Frame in Rehabilitation with U-shaped Metallic Yielding Damper.
93	Experimental studies of new hybrid inertia rotational friction damper and compare its performance with inertia rotational viscous damper
94	**Code and standards**
95	Evaluation of nonlinear static analysis of steel moment frames designed based on force and direct displacement based design under near field earthquakes
96	**Case and numerical studies on steel structure**
97	A Case study evaluation of a structure equipped with Friction Rotational Damper
98	Contribution of Steel Plate and Peripheral Frame in Optimized Design of Steel Plate Shear Wall with Stiffeners
99	Investigation on Base Level in Steel Buildings with Basement
100	Efficiency of Rocking behavior of Asymmetric steel braced frames in controlling seismic Torsional response
101	Assessment of through plate effect in behavior of multi-story X-braced frames

Page	Title
102	Developing Seismic Fragility Curves for Mid-rise Steel Moment Frames of Different Ductility Levels
103	Study for compactness of sinusoidal corrugated web I-sections
104	Investigation of Inelastic Local Buckling of Double Channel Section Beams and Comparison with Equivalent I-Section
105	Effects of arrangement of resistant skeleton of low-rise moment frames on structural seismic response
106	Evalution of the effects of battens on seismic behaviour built -up brace section
107	Evaluation of Steel Special Moment Frames drift affected by the far field earthquake in Iran
108	Fragility Assessment of Base-Isolated Structures With Lead Rubber Bearings and Natural Rubber Bearings Equipped With Shape Memory Alloy
109	Numerical investigation of the behaviour of reduced link section to column connections
110	Optimum design of structures using cultural algorithm
111	Optimum design of steel moment frames using improved particle swarm algorithm
112	Assessment of Steel Self-Centering Post-Tensioned Connection's Behavior Using Finite Element Method
113	Reliability-based Optimization of Steel Frames with Decision-making
114	Simulation of Crack Growthing of Steel Plate Shear Wall with Opening and Stiffener
115	Damage Detection in Steel Frames Using Frequency Response Functions
116	Stability Analysis of Stiffened Plates Using Mixed Method of Reproducing Kernel Particle Method and Bubble Finite Strip Method¬ (RKPM-FSM)

Page	Title
117	Causes and effects of delay in designing, fabrication and erection of huge steel structures in IRAN
118	Effect of Bolt Arrangements in Structural Response of Cold-formed Steel Structure
119	Identification of Nonlinearity (Plastic Hinge) in a Steel Member SDOF System Using the Frequency Response Functions (FRF) by the Earthquake Monitoring Data
120	Numerical Analysis of the link beam divergence braced frames under seismic forces

Corrosion and fire resistant steel structures

سازه های فولادی مقاوم در برابر آتش و خوردگی

Finite Element Investigation on the Behaviour of Open-Web Steel Beams Subjected to Fire

KADA Abdelhak[1], LAMRI Belkacem[2], BOUCHAIR Abdelhamid[3], MESQUITA Luis M.R[4]

Abstract

This paper presents a numerical investigation on the behaviour of open-web steel beams under high temperatures due to fire using finite elements simulations. The study includes parent beams without openings as well as castellated and cellular beams taking into account uniform and transient temperature rise, material and geometric non-linear behaviour. The input fire is based on the standard temperature-time curve ISO834. The thermal and mechanical analyses are performed using the temperature dependent material properties given by Eurocode3 part1-2 recommendations. The FE models are used to estimate the temperature at which the failure occurs under a fixed uniformly distributed mechanical load. The most commonly used types of web opening shapes are considered (hexagonal and circular) for simply supported beams. The study shows that the numbers of web-openings and cells as well as their shapes are of high importance for the behaviour of castellated steel beams under fire conditions. Results are related to temperature profiles in steel beam cross-sections, variation of displacements with respect to temperature change and critical temperatures.

Keywords

Open web beam, cellular beam, castellated beam, finite element, ISO834 fire, critical temperature

1. Laboratory of Structures, Geotechnics & Risks, University Hassiba-Benbouali of Chlef, Faculty of Civil Engineering & Architecture, Route de Sendjas, Chlef 02000, Algeria, kada_abdel@yahoo.com
2. Laboratory of Structures, Geotechnics & Risks, University Hassiba-Benbouali of Chlef, Faculty of Civil Engineering & Architecture, Route de Sendjas, Chlef 02000, Algeria, lamri_belkacem@yahoo.com
3. Université Clermont Auvergne, Institut Pascal, BP 10448, 63000 Clermont Ferrand, France
CNRS, UMR 6602, Institut Pascal, 63171 Aubière, France
, abdelhamid.bouchair@univ-bpclermont.fr
4. ISISE, Polytechnic Institute of Bragança, Campus Sta Apolónia Apartado 1134, 5300-857 Bragança, Portugal, lmesquita@ipb.pt

Finite Element Investigation on the Behaviour of Open-Web Steel Beams Subjected to Fire

KADA Abdelhak[1], LAMRI Belkacem[2], BOUCHAIR Abdelhamid[3], MESQUITA Luis M.R[4]

[1,2] Laboratory of Structures, Geotechnics & Risks, University Hassiba-Benbouali of Chlef, Faculty of Civil Engineering & Architecture, Route de Sendjas, Chlef 02000, Algeria, [1]kada_abdel@yahoo,com
[2]lamri_belkacem@yahoo.com
[3]Clermont Université, Université Blaise Pascal, Institut Pascal, BP 10448, 63000 Clermont Ferrand, France, hamid.bouchair@gmail.com
[4]ISISE, Polytechnic Institute of Bragança, Campus Sta Apolónia Apartado 1134, 5300-857 Bragança, Portugal, lmesquita@ipb.pt

Summary

This paper presents a numerical investigation on the behaviour of open-web steel beams under high temperatures rise due to fire using finite elements simulations with ANSYS software. Cases of study for solid parent steel elements as well as castellated and cellular beams are considered and take into account uniform and transient temperature rise, material and geometric non-linear behaviour. Input fire is the standard temperature-time curve ISO834 fire model and thermal and mechanical analyses are done using the effect of temperature dependent material properties according to Eurocode3 part1--2 recommendations for mechanical steel properties reduction. FE models which estimate failure temperatures are presented for two most commonly used types of web opening shapes including, hexagonal and circular for simply supported beams under uniformly distributed mechanical loading. The study shows that the numbers of web-openings and cells as well as their shapes are critical for the behaviour of castellated steel beams under fire conditions. Results are related to temperature profiles in steel beam cross-sections, variation of displacements with respect to temperature change and critical temperatures.

Keywords: Open web beam, cellular beam, castellated beam, finite element, ISO834 fire.

Introduction

In open-web steel beams, holes are designed to fit services and hence avoiding storey height limitation dilemma by gaining enough spaces beneath the beams [1]. However, at ambient condition the openings induce, substantial decrease of their load carrying capacity [2, 3] and several failure modes [4]. In the case of fire steel beams suffer a great reduction of yield stress and Young's modulus, under the effect of high temperatures [5, 6]. Especially for open-web steel beam structures, the elastic modulus of the steel reduces at a faster rate than the yield strength causing local instability at elevated temperatures [7].

At present there is only the design guide addressing beams with web openings at ambient temperature known as annex N from EC3 [8]. Under fire conditions; studies on open-web beams cases were to seek improvement in design rules by experiments and numerical analyses on isolated members or in redundant structures [9, 10].

There is a need still for research work based on FE analysis to study open-web steel beams under such conditions. In this paper, open-web steel beams having 10, 12 and 16 holes are studied under elevated temperature with three different web opening geometries, hexagonal and circular. Analyses are done using ANSYS [11] finite element models, for solid beam a 3- Node quadrature "BEAM189", 4-node SHELL131 for thermal analysis and 4-node structural SHELL181models are used for plain and open-web beams. The primal model considers uniform high temperature rise on the steel sections and for the lateral thermal analysis is used to account for high temperature change with respect to time under ISO834 fire curve.
Thermo-mechanical analysis of each model produced critical temperature for each and lateral displacements at beam failure as well as Von-Mises stress distribution upon Vierendeel mechanism formation around openings.

Comparison of results for maximum vertical deflections, critical temperatures and failure modes is done among the different types of open-web beams.

Method

The structural model used this study was developed for three different web opening geometries, hexagonal and circular shapes for castellated and cellular beams respectively. A parametric study based on the following input data [12] to workout limiting temperatures for numerical models are outlined as follows:

1. Model Geometry and guidelines

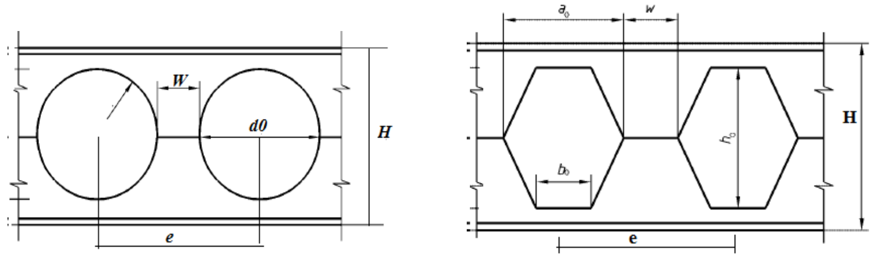


Figure 1. Geometric shapes & Properties of beams with web opening

The width w of the web post should be at least equal to 130 mm;
The ratio e/a_0 should at least equal to 1.25;
The ratio h/a_0 should be at least equal to 1.25 and not greater than 4.0;
Where e is the spacing between regular openings and h is the total height of the beam
Diameter of cells and the width of hexagons is a_0 =38 cm and kept constant for all cases.

The beams of steel grade S355 are simply supported, pin-roller, and subjected to a distributed load.

A preliminary design at ambient using ACB+ software [13] was conducted to work out the ultimate load qult that checks, cross-section resistance at web opening and post locations, shear buckling of the web and resistance of the beam to the lateral torsional buckling according to the principles of Eurocode 3 [14]. Table 1 is a summary of the dimensions and load design values q_{Ed} at room temperature for cases of study.

Table 1. Open web beams dimensions and loads

Dimensions	CELL10/HEX10	CELL11	CELL12/HEX12	CELL13
w(mm)	285	220.02	170	152
e(mm)	665	600.02	550	532
α=e/a0	1.8	1.6	1.5	1.4
q_{Ed}(kN/m)	73.51	72.84	73.33	72.89

2. Fire and thermo mechanical properties

Fire curve input is according to nominal fire ISO834, defining gas temperature θ_g in °C, by the following equation (Eq.1) with time t in minutes:

$$\theta_g = 20 + 345 log_{10}(8t + 1) \quad (1)$$

Input of the specific heat of steel material, C_a (J/kgK), is according to the following equations (Eqs. 2) of Eurocode 3 part1-2 [14]:

$$20°C \leq \theta_a < 600°C: C_a = 425 + 7.73x10^{-1}\theta_a - 1.69x10^{-3}\theta_a^2 + 2.22x10^{-6}\theta_a^3 \quad (2a)$$

$$600°C \leq \theta_a < 735°C: \quad C_a = 666 + \frac{13002}{738 - \theta_a} \quad (2b)$$

$$735°C \leq \theta_a < 900°C: \quad C_a = 545 + \frac{17820}{\theta_a - 731} \quad (2c)$$

$$900°C \leq \theta_a < 1200°C: \quad C_a = 650 \quad (2d)$$

Input of the conductivity of steel material, λ_a (W/mK), is according to the following equations (Eqs. 3) of Eurocode 3 part1-2:

$$20°C \leq \theta_a < 800°C: \quad \lambda_a = 54 - 3.33x10^{-2}\theta_a \quad (3a)$$

$$800°C \leq \theta_a < 1200°C: \quad \lambda_a = 27.3 \quad (3b)$$

The input steel mechanical behaviour under fire condition follows the stress-strain relationships given in EN1993-1-2 [14] and in all simulations a nominal value for the structural strength fy_{20} of 355 N/mm2 for open-web steel beams.

Simulations on ASYS software are performed first for thermal transiant analysis using SHELL 131 finite element followed in second by mecanical analysis using SHELL 181 finite element to get critical température at failure.

Results

For the case of solid beam parent element thermal analysis results is presented and a comparison is made with analytical approach.

The finite element thermal transient analysis shows steel temperature curves on both flanges and web which are plotted against Eurocode3 steel section uniform temperature figure 12. For mechanical analyses for solid beam, the shell finite element model is based upon transient thermal analysis producing non-uniform temperatures within the beam cross-section.

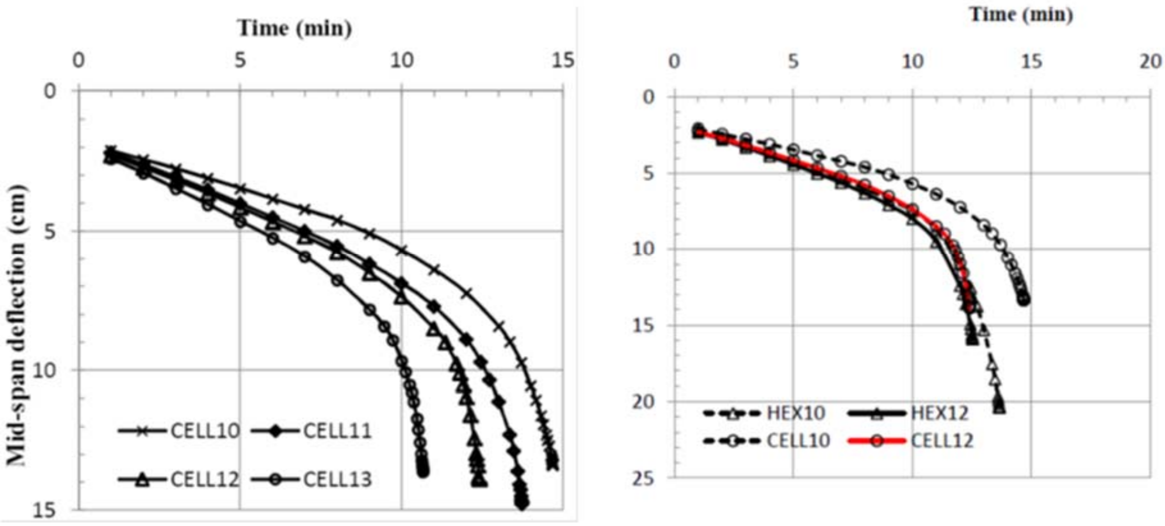
For the case of cellular beams, the study considers different number of apertures referred to as CELL10, CELL11, CELL12, CELL13, resulting in different spacing ratio α which obeys to the prescribed geometry limitations.

Results from thermo-mechanical analyses of cellular and castellated beams, in terms of critical temperatures, times and mid-span deflection are summarised in table2.

Table 2. Structural finite element fire analyses results for cellular and castellated beams for fire load η=0.6

Beam type	CELL10	CELL11	CELL12	CELL13	HEX10	HEX12
t_{lim} (min)	14.95	13.93	12.38	10.47	13.65	12.52
Θ_{lim}(°C))(web)	717	704	685	659	702	689
Mid-span deflection(cm)	16.44	16.83	13.03	11.66	20.37	15.91

Plots of mid-span deflection and a comparison of fire resistance of cellular and castellated beams are illustrated in Fig. 2.



(a) Cellular beams (b) Comparison cellular vs catellated beams

Figure 2. Mid-span deflection for open-web steel beams

Discussion/Conclusions

Fig.2(a) shows that the fire resistance decreases with the opening spacing ratio α. Fig.2(b) shows that the cellular CELL12 performed well compared to the castellated beam HEX12 while its opening area is slightl greater.

Mechanical analyses results for the solid beam shows a higher critical temperature of 705°C compared to 626°C of EC3 simple calculation. The corresponding limiting time is 16.6 minutes with a maximum vertical displacement of 27.4 cm.

Table2 shows that critical temperature decreases as the number of openings increases and that the maximum vertical displacements are higher for higher number of holes in the web.

The behaviour of steel beams with web apertures under fire condition is complex and the aim of the paper is to presents a numerical investigation to evaluate their performance at elevated temperature using ANSYS software. Finite elements models using shell elements were developed to work out major design parameters in terms of critical load, limiting time, critical temperature and mid-span deflection encountered during the structural beam response under fire. The simulations helped to monitor these parameters in fire condition considering both material and geometrical non-linearity. At room temperature the cellular beams were satisfactory checked for both to plastic and instability resistance criteria using ACB+ design tool [?]. Under elevated temperatures the finite element thermal analysis shows that web post temperature is higher than in the solid beam and that it gets extra heat from the opening edge. Mechanical finite element analysis predicted Vierendeel bending failure for higher α values and web post buckling for smaller α value.

References

[1] Kaveh A, Shokohi F. (2014). Cost optimization of castellated beams using charged system search algorithm, *Iranian Journal of Science and Technology, Transactions of Civil Engineering, No. C1, 38, 235-249.*

[2] Lawson RM., Lim J., Hicks SJ. & Simms WI (2006). Design of composite asymmetric cellular beams and beams with large web openings. *J Constr Steel Res;62(6):614–629*.

[3] Soltani M. R., Bouchaïr A. & Mimoune M. (2011). Nonlinear FE analysis of the ultimate behavior of steel castellated beams, *Journal of Constructional Steel Research, Vol. 70, No. 2012, 101-114.*

[4] Kerdal D., Nethercot D.A. (1984). Failure modes for castellated beams, *J. Constr. Steel Res., 4(4), 295-315.*

[5] Vassart O., Hawes M., Simms I., Zhao B., Franssen JM., Nadjai A. (2012). Fire resistance of long span cellular beam made of rolled profiles, *FICEB, European Commission final report.*

[6] Naili E., Nadjai A., Han S., Ali F. & Choi S. (2011). Experimental and Numerical Modelling of Cellular Beams with Circular and Elongated Web Openings at Elevated Temperatures, *Journal of Structural Fire Engineering*, *Volume 2 · Number 4 , 289-300.*

[7] Vassart O., Bouchaïr A., Muzeau J.P., Nadjai A. (2008). Analytical model for the web post buckling in cellular beams under fire, *Proc. SIF 2008, 813-823.*

[8] EC3 – ENV 1993 – Amendement A2 - Annexe N (1995): Ouvertures dans les âmes de poutres – Document CEN/TC 250/SC3/N477E - Mars 1995.

[9] Nadjai, A., Petrou K., Han S., Ali F. (2016). Performance of unprotected and protected cellular beams in fire conditions**.** *Construction and Building Materials, 105, 579-588.*

[10] Ellobody E, Young B. (2015). Nonlinear analysis of composite castellated beams with profiled steel sheeting exposed to different fire conditions, *Journal of Constructional Steel Research, 113, 247-260.*

[11] ANSYS ver 14.5.7

[12] Bitar D., Martin P.O., Galea Y. & Demarco T. (2006), Poutres cellulaires acier et mixtes : Partie 1, proposition d'un modèle pour la résistance des montants , *Revue Construction Métallique (CTICM), n°1, 15-39.*

[13] ACB+ , version 3.08, ArcelorMittal

[14] EN 1993-1-2 (2005) Eurocode 3. Design of steel structures. General rules. Structural fire design